FOREST PEST MANAGEMENT

3430 BIOLOGICAL EVALUATION
R2-92-4

Western Spruce Budworm

Creede and Del Norte Districts
Rio Grande National Forest

United States Department of Agriculture
Forest Service
Forest Pest Management
Denver, Colorado

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ABSTRACT

Western spruce budworm populations have been at outbreak levels throughout much of the mixed conifer type on the Creede and Del Norte Districts of the Rio Grande National Forest since the early 1980's. In early 1992, the Rio Grande National Forest requested a biological evaluation of the spruce budworm situation on the two districts. Of primary interest to the Forest were: the current level of budworm damage along the Silver Thread Scenic Byway; the prognosis for the budworm outbreak; and a list of management options. The Forest identified six areas to be included in the survey for this evaluation.

Field work for this evaluation was conducted in the summer of 1992. A total of 306 branch samples were collected from 51 plots at the 6 areas. Current defoliation levels and budworm egg mass densities, used to predict 1993 defoliation, were determined from the branch samples.

In 1992, an estimated 50,000 acres of primarily mixed conifer forests were defoliated by the budworm on the two districts. Defoliation ranged from less than 1 percent of the 1992 needles at Agua Ramon to 55 percent of the 1992 needles at the Haney Canyon area. Egg mass counts indicate that western spruce budworm populations will remain at outbreak levels in all of the sampled areas through 1993.

For undeveloped forest land, silvicultural strategies that reduce stand susceptibility and vulnerability are recommended. For developed forest lands, direct suppression of the budworm outbreak is recommended.

INTRODUCTION

In early 1992, the Rio Grande National Forest requested a biological evaluation of the western spruce budworm situation on the Creede and Del Norte Districts. Of primary interest to the Forest were: the current level of budworm damage along the Silver Thread Scenic Byway; the prognosis for the budworm outbreak; and a list of management options. The Forest identified six areas to be included in the survey for this evaluation.

Western spruce budworm populations have been at outbreak levels throughout much of the mixed conifer forest type on the Creede and Del Norte Districts of the Rio Grande National Forest since the early 1980's (Raimo, 1984). During the last decade, the area of visible defoliation has greatly fluctuated. In 1992, the insect caused visible defoliation on an estimated 50,000 acres on the two districts. The most severe defoliation has been occurring along the corridors of Highway 149 and Highway 160 and is centered around the town of South Fork. The portion of Highway 149 between the towns of Lake City and South Fork was designated the Silver Thread Scenic Byway in 1991. Much of the mixed conifer type along the scenic byway were defoliated in 1992.

The western spruce budworm, a native species, is the most widely distributed and destructive defoliator of coniferous forests in western North America. About 5 million acres are infested annually in the western part of the continent, and about 247 million acres of western forests are considered susceptible (Brookes et al., 1987).

The host/pest dynamics of the budworm are not fully understood. It is believed that harvesting methods, especially the removal of mature ponderosa pine from mixed conifer stands, along with the effective prevention and control of fires since the early 1900's resulted in the development of dense stands with a higher percentage of shade tolerant, climax tree species favorable to the budworm.

Natural biological factors such as parasites and pathogens generally do not appear to be important in regulating increasing budworm populations (McKnight, 1967). However, a population collapse on the Rampart Range in Colorado in 1963 was associated with a significant increase in the parasite Bracon Poliventris (Cushman) (McKnight, 1967).

Unfavorable weather, particularly late spring frosts, have had the most dramatic effect on budworm populations in the West (Klein, 1967; Fellin et al., 1972; McKnight, 1971). Collapse of budworm outbreaks along the northern Front Range of Colorado in 1945 and on the Shoshone National Forest in 1936 followed late spring frosts which decimated the budworm populations (McKnight, 1967; Lister, 1969).

Swetnam and Lynch (1989) performed a tree ring reconstruction of the history of western spruce budworm outbreaks on the Colorado Front Range and the Sangre de Cristo Mountains of New Mexico. At least nine outbreaks were identified between 1700 and 1983. The average duration of the outbreaks was 12.9 years. The average interval between initial years of successive outbreaks was 34.9 years. The average maximum and periodic growth reductions were 50% and 21.7%, respectively. They found that there were relatively long periods of reduced budworm activity in the first few decades of the twentieth century, and since that time outbreaks have been more synchronous. They hypothesize that the increased synchroneity of outbreaks in the later half of the twentieth century is due to changes in age structure and species composition following harvesting and fire suppression in the late nineteenth and early twentieth centuries.

The factors affecting a stand's susceptibility to western spruce budworm are host phenology, stand composition, stand density, height structure, stand vigor, stand maturity, stand size, and climate and topography (Brookes et al., 1987).

Host Phenology

Synchronization of budburst with spring larval emergence is important to the budworm. Generally, host species on which buds break after larval emergence are less susceptible than species that have earlier budburst.

Stand Composition

In stands composed mostly of host trees - particularly Douglas-fir and true firs - susceptibility increases with the proportion of shade tolerant species present.

Stand Density

Susceptibility to the budworm increases as the density of host species increases. Thick, dense stands of true firs or Douglas-fir have tremendous amounts of foliage biomass and provide budworm with ample habitat. Larval mortality during dispersal is reduced in dense stands because the nearly continuous crown cover prevents larvae from falling to the ground, where they are prey for ants, spiders, and other predators.

Height Structure

Multi-storied host stands are better habitat for budworm than are even-aged, one-storied stands. Intermediate crown layers tend to reduce larval mortality during dispersal and increase food available to the budworm. During an outbreak, mature larvae often deplete foliage on large trees and spin down in search of additional food, frequently landing on intermediate crown layers where they can complete their life cycle. Further, the lower canopies of multistoried stands usually are composed of shade tolerant conifers, the preferred host of the budworm.

Stand Vigor

Fast-growing, healthy stands are less susceptible than stagnated, stressed stands. Foliage quality in stressed stands is more favorable to the budworm and tends to promote insect survival.

Stand Age

Even-aged stands 1 to 20 years old are low in susceptibility to the budworm. Susceptibility increases as stand age increases. Stands 40 to 60 years old have high foliage biomass and have developed dominance classes. The irregular canopy of older stands promotes the growth and survival of the budworm.

Stand Size

Host stands of small acreages isolated in non-host types are not likely to be infested by budworms.

Climate and Topography

Stands in geographic areas with relatively warm, dry, spring climate are more susceptible and incur more injury than stands in wet, cold areas because budworm larval development is favored by warm, dry conditions.

TECHNICAL INFORMATION

Insect: Western spruce budworm, _Choristoneura_ _occidentalis_, Freeman

Hosts: Douglas-fir, _Pseudotsuga_ _menziesii_ (Mirb.) Franco
White fir, _Abies_ _concolor_ (Gord. & Glend.) Lindl.
Subalpine fir, _Abies_ _lasiocarpa_
Blue spruce, _Picea_ _pungens_ Engel.
Engelmann spruce, _Picea_ _engelmannii_ Parry

Life History: The western spruce budworm completes one generation per year.

STAGE	TIME	LOCATION ON HOST
Egg	August	On needles
Small Larvae	Overwinter	In hibernacula (microscopic silken cocoons) on branches and trunk
Larger larvae	June	On buds and new branch tips
Pupae	July	On branch tips
Adults	August	In flight

Evidence of infestation:

1. Presence of partially eaten foliage (primarily on new branch tips).

2. Hairless, olive green to brown larvae feeding on current year's needles.

3. Current year's shoots webbed together by larvae.

4. Defoliation most evident in upper crowns of trees.

5. From a distance, in late summer, hillsides of host trees appear to have a reddish-brown cast.

6. Trees dying from the top downward after several years of heavy defoliation.

EVALUATION METHODS

Egg mass density is used to monitor and predict spruce budworm population trends, evaluate effects of control projects and to forecast defoliation. Defoliation predictions are based on the density of new masses collected from the midcrown of host trees (Carolin and Coulter, 1959; 1972). Egg mass density classes and associated defoliation are displayed in Table 1. These classes are adopted from McKnight et al. (1970) and were refined by Linnane (1978) based on four years of data from the fixed plot, tree cluster, sampling scheme.

Table 1. Defoliation prediction classes for western spruce budworm egg mass sampling in Region Two.

Class	Mean Number of New Egg Masses Per Square Meter Foliage	Predicted Defoliation of New Growth
1	1.6 or less	0 - 10 % (Undetectable)
2	1.7 to 10	10 - 35 % (Light)
3	10.1 or more	> 35 % (Moderate to Severe)

The Creede and Del Norte Districts identified 6 areas which they considered high priority for the egg mass and defoliation survey. An egg mass density survey was conducted during August and September after the egg deposition period. A total of 306 branch samples were collected from 51 plots at 6 infested areas on the two Districts. The legal descriptions of plot locations are listed in Appendix A. Maps showing area, cluster and plot locations are presented in Appendices B-H.

The sampling design followed that recommended by Schmid and Farrar (1982). At each area, 3, three-plot clusters were established. One exception occurred at the Agua Ramon area where limited host type allowed the establishment of only 2, three-plot clusters. The minimum distance between plot clusters was .25 miles. The minimum distance between plots within a cluster was 30 yards. Six dominant or codominant host trees were sampled at each plot. One 27-inch branch was pruned from the midcrown of each tree for a total of six branches per plot. The foliage samples were bagged, labeled, and transported to the laboratory, where new egg mass densities were determined. A microscope was used to separate new from old egg masses.

Estimates of current year defoliation levels were made from the egg mass sample branches. For each branch sample, the new growth on 25 randomly selected branch tips was examined in the laboratory to determine the percentage of defoliation. Defoliation estimates are based on the percent of missing needles determined by the ocular examination of each branch tip. The following six class system for rating the defoliation of each branch tip was used:

Ocular Estimate of Defoliation (%)	Branch Tip Defoliation Class
0	0
1 - 25	1
26 - 50	2
51 - 75	3
76 - 99	4
100	5

RESULTS

The results of the survey on the Creede and Del Norte Districts of the Rio Grande National Forest are presented in Table 2.

Defoliation levels in the six sample areas ranged from less than 1 percent of the 1992 needles at Agua Ramon to 55 percent of the 1992 needles at the Haney Canyon area.

Egg mass counts indicate that western spruce budworm populations will remain at outbreak levels in all of the sampled areas through 1993. In 1993, light defoliation is expected on all of the sampled areas except Haney Canyon where moderate to severe defoliation is predicted. The egg mass densities at Alder Creek and DelNorte Peak are near the border line between the light and moderate to severe expected defoliation classes.

Table 2. Results of the 1992 Western Spruce Budworm Survey on the Del Norte and Creede Ranger Districts, Rio Grande National Forest.

Area	1992 Defoliation (% New Growth)	S.E.	Mean Number of New Egg Masses per Square Meter Foliage	S.E.	1993 Defol. Forecast (% New Growth)
Agua Ramon	< 1	± .1	1.7	± 1.7	10 - 35
Alder Creek	42	± .3	9.6	± 1.9	10 - 35
Beaver Creek	28	± .1	4.7	± 2.1	10 - 35
Del Norte Peak	40	± .5	9.7	± 4.3	10 - 35
Haney Canyon	55	± .6	15.0	± 2.1	> 35
Horseshoe Mountain	25	± .4	2.7	± .7	10 - 35

MANAGEMENT ALTERNATIVES

A. Maintain Current Management

This is the no action alternative. Under this alternative, the western spruce budworm outbreak will continue dependent on natural factors. Budworm populations will eventually decline as a result of a combination of natural factors including; starvation, unfavorable weather, disease, and predation and parasitism.

Under this alternative the budworm outbreak will continue to impact the forests of the Creede and Del Norte Districts. The greatest impact of the western spruce budworm outbreak on the Creede and Del Norte Districts has been on the aesthetics of the mixed conifer forests along the Silver Thread Scenic Byway. The annual defoliation that has occurred in these stands for the last several years has resulted in large number of thin-crowned host trees that are near death. If the impacts of this outbreak are similar to those observed elsewhere in Colorado, an average 10 - 20 percent of the mature Douglas-fir and white fir may die throughout the infested area before budworm populations return to endemic levels. Some of this mortality may be caused by Douglas-fir bark beetles, Dendroctonus pseudotsugae which may attack mature trees weakened by repeated defoliation. The amount of mortality in a stand will depend on that stand's susceptibility to budworm outbreaks and it's vulnerability to defoliation. In some stands, more than 50 percent of the mature Douglas-fir and white fir may die, while other stands may suffer only minimal mortality.

[illegible]

[illegible] and the Rural Districts, [illegible]

[illegible]

The [illegible] has [illegible]

[illegible]

[illegible] of mortality [illegible]

[illegible]

Under this alternative, defoliation, top-kill, and tree mortality will continue to affect the scenic quality of the forested landscapes along the Silver Thread Scenic Byway. Studies by Daniel (1981) indicate that budworm defoliation will reduce the quality of mid-range vistas of forested hillsides. These effects may be short-term, occurring during the peak years of the outbreak. Since most of the stands in the outbreak area are composed of a mixture of budworm host and non-host trees, the aesthetic impact of the outbreak along the visual corridor of the scenic byway will begin to diminish during the decade following the outbreak as dead host trees fall.

Increased dead-fall can lead to increased intensity and severity of wildfires. Wildfires occurring in areas affected by the budworm could be more difficult to control and can result in more environmental impact than wildfires occurring outside the budworm outbreak areas.

In addition to mature tree mortality, understory host tree mortality may range from 25 to 75 percent. Other expected host tree impacts are listed below:

Host Tree Damage Estimates For The Outbreak Area

Growth Loss	30 %
Top-kill	35 %
Cone Crop Losses	90+ %
Christmas Tree Value	90+ %

B. Silvicultural Strategies to Reduce Stand Susceptibility/Vulnerability

Even-aged management. Even-aged silvicultural systems are preferred in locations having a history of western spruce budworm outbreaks. Shelterwood prescriptions which attempt to maintain a mix of tree species can ameliorate existing budworm impacts and help reduce stand susceptibility to future outbreaks.

Whenever a seed cut of a two-step shelterwood is to be implemented in the budworm outbreak area, ponderosa pine and other budworm non-host species should be favored as seed trees. When an inadequate number of non-host seed trees exists in a stand, care must be taken to select budworm host trees that appear to be in the best condition while maintaining an even spacing of seed trees.

In stands entirely composed of budworm host species, 15-20 of the most vigorous trees in the dominant and codominant crown classes should be left per acre. Although this leave tree density would be high for seed cuts in healthy stands, we may assume that some of the leave trees will not survive the budworm and Douglas-fir beetle infestations. Leaving 15-20 trees per acre should help to ensure an adequate seed source even if 25 percent of the leave trees die before producing seed. The markers should strive to attain even spacing of the leave trees but leaving the most vigorous trees in the units is most important.

Opening up stands will have a negative impact on the budworm but estimating the magnitude of this impact is impossible. The reduction of stand stocking levels should also have a positive effect on the residual stand as competition for available water and nutrients will be reduced. However, as long as outbreak budworm populations persist in the units, the amount of seed produced by the leave trees will be minimal because budworms destroy the staminate and pistillate cones of Douglas-fir. Hopefully, the seed bed will not be lost to competing vegetation between harvest and production of adequate seed supply. According to Fowells (1965), Douglas-fir are capable of dispersing their seed a distance equal to six tree lengths. This means it may be necessary to plant openings larger than 3 acres to augment natural regeneration.

Uneven-aged management. Western spruce budworm outbreaks tend to decimate host trees occupying lower canopy levels. Therefore, when management objectives mandate the use of only uneven-aged management systems, stand surveys should be conducted to determine whether adequate stocking exists in the younger age classes. If adequate stocking in the younger age classes is lacking, rendering uneven-aged management unfeasible, then even-aged management should be implemented or stand treatment should be deferred. If adequate stocking exists and uneven-aged management is feasible, then the target basal area of the residual stands should be considered. Work in mixed conifer stands in New Mexico has demonstrated that in order to reduce the susceptibility of the residual uneven-aged stand to western spruce budworm, stand basal areas need to be reduced to very low levels. When stands consist of a majority of budworm host trees, target basal areas for the residual stands may need to be between 50 and 60 square feet.

Intermediate Cuts. Thinnings and sanitation/salvage may be implemented to:

1.) improve stand growth and vigor which reduces stand vulnerability to budworm defoliation;
2.) favor non-host trees;
3.) remove host trees in the lower crown classes to create a less budworm-friendly stand structure; and
4.) prevent excessive fuel loading.

Even though leave trees may be defoliated during heavy outbreaks, they tend to recover faster than defoliated trees in unthinned stands (Schmidt, 1978).

C. Direct Suppression

The use of insecticides remains the only practical alternative for immediate reduction of budworm populations to prevent damage and to protect foliage. Two classes of insecticides are operational - biological and chemical.

Insecticides can be used to:

1.) aerially treat the entire infestation;
2.) aerially treat high-value stands; or
3.) treat individual high-value trees using ground equipment.

Direct suppression with insecticides to reduce budworm populations is a short-term management technique. A successful application of insecticides may, at best, reduce budworm populations for 5 years and delay damaging defoliation for 3 to 5 years after treatment (Telfer, 1983).

Results of large scale spray projects against the budworm in New Mexico indicate that insecticide applications are most effective when applied to low density budworm populations (< 20 larvae per 100 buds) over an entire infestation or entomological unit. An entomological unit is a portion of the susceptible host type usually defined by physical features or stand composition. A large infested area is divided into entomological units in order to facilitate the administration of a direct suppression project. When insecticide applications are targeted at limited areas (stands, scenic corridors, or recreation areas) with high density budworm populations (> 20 larvae per 100 buds), annual applications will be necessary to achieve treatment benefits (Rogers, 1984). Larval densities are determined just before spraying.

Applications must be carefully timed to larval development and bud flush, i.e., when 20 percent of the larvae are in the fifth and sixth instars and buds are 85 to 90 percent flushed.

Several formulations of at least six compounds are currently registered for use against the western spruce budworm. The most frequently used are:

1.) Carbaryl (carbamate insecticide)
2.) Acephate (organophosophate insecticide)
3.) *Bacillus thuringiensis* (Bt) (bacterial insecticide)

The following are examples of 1992 aerial application costs in southwestern Colorado using a fixed-wing, turbine-powered Air Tractor (Ayers, 1993):

Insecticide	Project Size	Cost
carbaryl	< 40 acres	12.80/ac
carbaryl	40 or more acres	10.97/ac
Bt	< 40 acres	21.76/ac
Bt	40 or more acres	19.25/ac

Of course, the above costs do not include costs of NEPA compliance, pre-treatment and post-treatment evaluations, and other administrative/support costs.

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Carbaryl [illegible]
Acephate (Orthene) [illegible] (chemical)
Bacillus thuringiensis (Bt) (bacterial insecticide)

[illegible] examples of 1982 costs [illegible]
using a fixed-wing [illegible]

Insecticide	Project Size	Cost
[illegible]	[illegible]	[illegible]
carbaryl	[illegible] acres	[illegible]
Bt	[illegible]	[illegible]
Bt	[illegible]	[illegible]

The above costs [illegible] complete,
[illegible] and post-treatment [illegible]

RECOMMENDATIONS

The western spruce budworm is a long-term forest management problem which must be addressed through long-term forest planning. The western spruce budworm should be considered when developing forest standards and guidelines and, most importantly, when describing desired future conditions for management areas.

For undeveloped forest land, I recommend the alternative, **Silvicultural Strategies to Reduce Stand Susceptibility/Vulnerability**.

On undeveloped forest land, greater attention should be paid to stand conditions and stand treatments which influence budworm populations and budworm impacts. Forest susceptibility and vulnerabilty to budworm outbreaks should be considered during project level analysis, i.e., when developing project proposals and stand prescriptions within budworm host types. In particular, the implementation of uneven-aged management prescriptions in budworm host types needs careful attention. Many uneven-aged prescriptions improve budworm habitat, increasing the probability of future outbreaks which may preclude stand regulation and/or sustainability.

For developed forest lands, I recommend the alternative, **Direct Suppression**, using ground equipment to protect individual high-value trees. Developed forest lands include improved campsites and recreation facilities and administrative sites.

Annual applications of insecticides may be necessary during the outbreak period to achieve the objective of this alternative because direct suppression is a short term approach to budworm management which has no effect on stand susceptibility or vulnerability.

None of the areas identified by the Forest as high priority for our budworm survey included improved campsites, recreation facilities or administrative sites.

ACKNOWLEDGEMENTS

I would like to express my appreciation for the assistance of Erik Johnson and Kim Kennedy-Roy who collected most of the field data and endured the tedious task of counting egg masses in the laboratory.

The business ... long-term [illegible]

[illegible] Forest ... to represent the alternatives [illegible]

[illegible] of project level [illegible]
[illegible] implementation of [illegible] and management [illegible]
needs careful attention. Many [illegible]
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have the capability [illegible]
[illegible] capability [illegible]

Areas identified by the forest as high priority for [illegible] include improved campsites, recreation trail [illegible]

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APPENDIX A

Locations of 1992 Western Spruce Budworm Sampling Plots

Area	Cluster	Plot	Location
Agua Ramon	1	1	T.40 N, R.4 E, NW 1/4 Sec. 19
		2	T.40 N, R.3 E, NE 1/4 Sec. 13
		3	T.40 N, R.3 E, SE 1/4 Sec. 12
	2	1	T.40 N, R.3 E, SE 1/4 Sec. 12
		2	T.40 N, R.3 E, SE 1/4 Sec. 12
		3	T.40 N, R.3 E, SE 1/4 Sec. 12
Alder Creek	1	1	T.40 N, R.3 E, SE 1/4 Sec. 6
		2	T.40 N, R.3 E, NE 1/4 Sec. 6
		3	T.40 N, R.3 E, NE 1/4 Sec. 6
	2	1	T.40 N, R.3 E, SE 1/4 Sec. 9
		2	T.40 N, R.3 E, SW 1/4 Sec. 9
		3	T.40 N, R.3 E, SW 1/4 Sec. 9
	3	1	T.40 N, R.3 E, SE 1/4 Sec. 9
		2	T.40 N, R.3 E, NE 1/4 Sec. 9
		3	T.40 N, R.3 E, SE 1/4 Sec. 9
Beaver Creek	1	1	T.38 N, R.3 E, SW 1/4 Sec. 9
		2	T.38 N, R.3 E, NE 1/4 Sec. 16
		3	T.38 N, R.3 E, SE 1/4 Sec. 16
	2	1	T.38 N, R.3 E, NE 1/4 Sec. 10
		2	T.38 N, R.3 E, SE 1/4 Sec. 10
		3	T.38 N, R.3 E, NW 1/4 Sec. 14
	3	1	T.38 N, R.3 E, NE 1/4 Sec. 7
		2	T.38 N, R.3 E, NE 1/4 Sec. 7
		3	T.38 N, R.3 E, NW 1/4 Sec. 8
Del Norte Peak	1	1	T.39 N, R.4 E, NE 1/4 Sec. 7
		2	T.39 N, R.4 E, NW 1/4 Sec. 8
		3	T.39 N, R.4 E, SW 1/4 Sec. 8
	2	1	T.39 N, R.4 E, SE 1/4 Sec. 8
		2	T.39 N, R.4 E, NW 1/4 Sec. 16
		3	T.39 N, R.4 E, SW 1/4 Sec. 16
	3	1	T.39 N, R.4 E, NE 1/4 Sec. 14
		2	T.39 N, R.4 E, NW 1/4 Sec. 13
		3	T.39 N, R.4 E, NE 1/4 Sec. 13

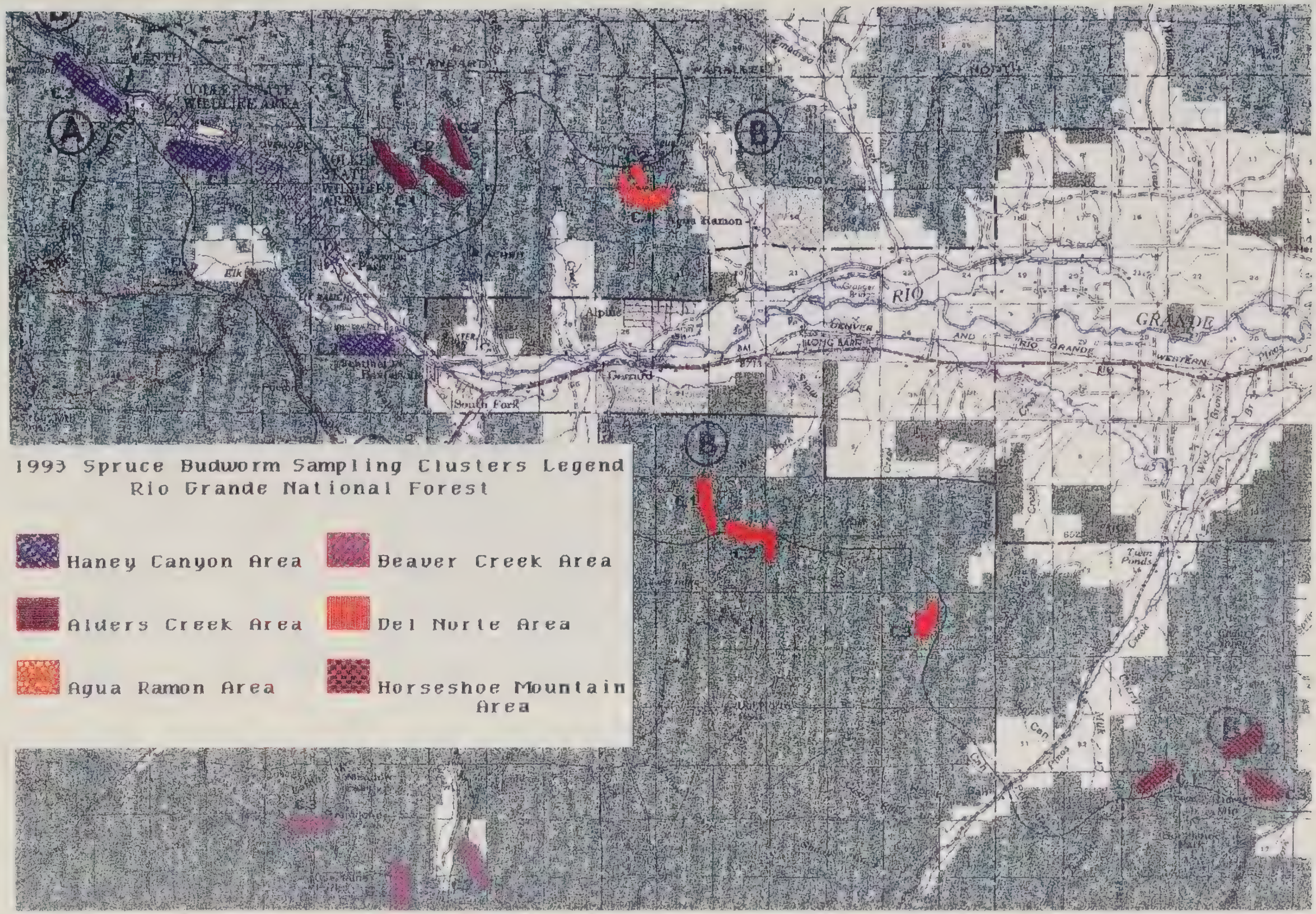
APPENDIX A (Cont'd)

Locations of 1992 Western Spruce Budworm Sampling Plots

Area	Cluster	Plot	Location
Haney Canyon	1	1	T.40 N, R.2 E, NW 1/4 Sec. 11
		2	T.40 N, R.2 E, SW 1/4 Sec. 11
		3	T.40 N, R.2 E, NE 1/4 Sec. 10
	2	1	T.40 N, R.3 E, SE 1/4 Sec. 29
		2	T.40 N, R.3 E, SW 1/4 Sec. 29
		3	T.40 N, R.3 E, SE 1/4 Sec. 30
	3	1	T.40 N, R.2 E, SE 1/4 Sec. 4
		2	T.40 N, R.2 E, NW 1/4 Sec. 4
		3	T.41 N, R.2 E, SW 1/4 Sec. 33
Horseshoe Mountain	1	1	T.38 N, R.5 E, NE 1/4 Sec. 4
		2	T.38 N, R.5 E, NW 1/4 Sec. 4
		3	T.38 N, R.5 E, SW 1/4 Sec. 3
	2	1	T.39 N, R.5 E, NW 1/4 Sec. 35
		2	T.39 N, R.5 E, SW 1/4 Sec .35
		3	T.39 N, R.5 E, SE 1/4 Sec. 34
	3	1	T.39 N, R.5 E, SE 1/4 Sec. 2
		2	T.39 N, R.5 E, SE 1/4 Sec. 2
		3	T.39 N, R.5 E, SW 1/4 Sec. 2

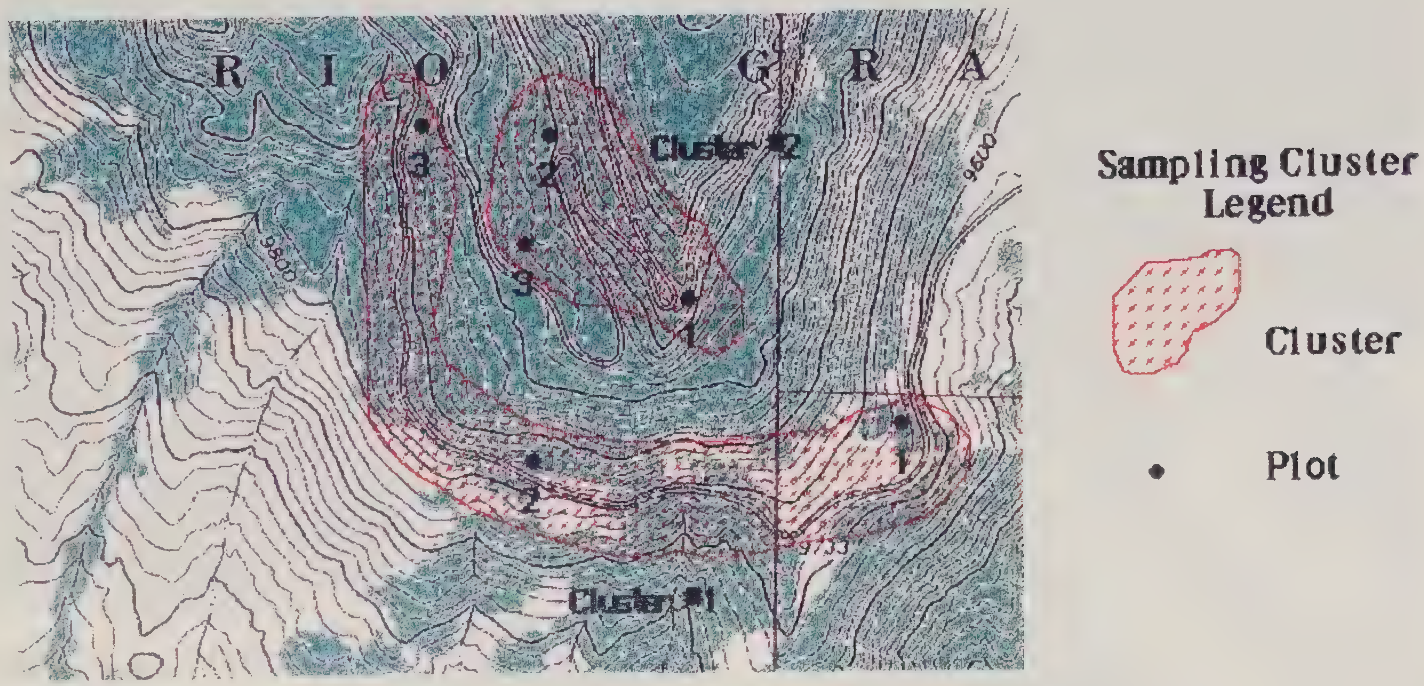
APPENDIX B

1993 Spruce Budworm Sampling Clusters
Rio Grande National Forest



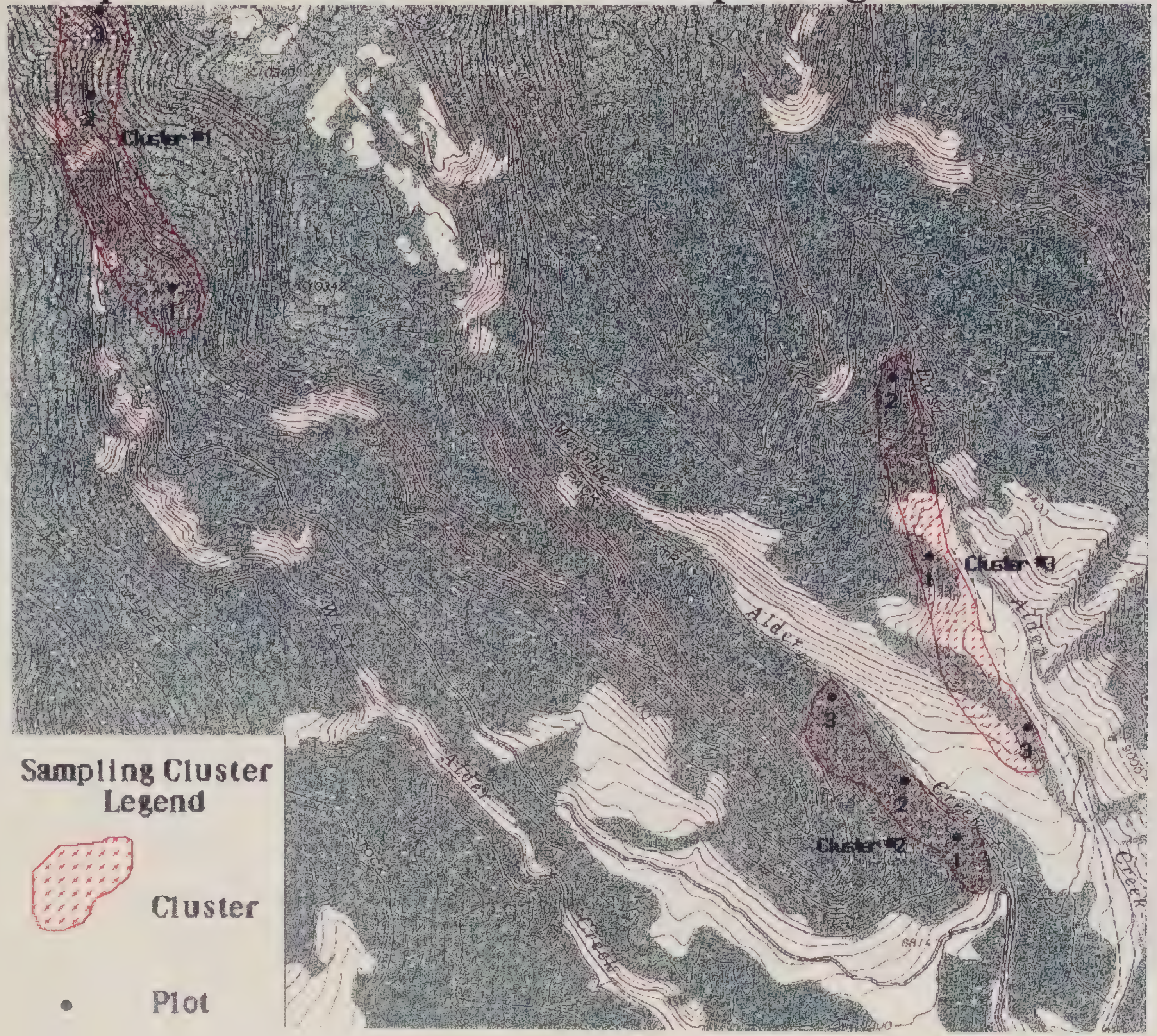
APPENDIX C

Agua Ramon Area
Spruce Budworm Sampling Clusters



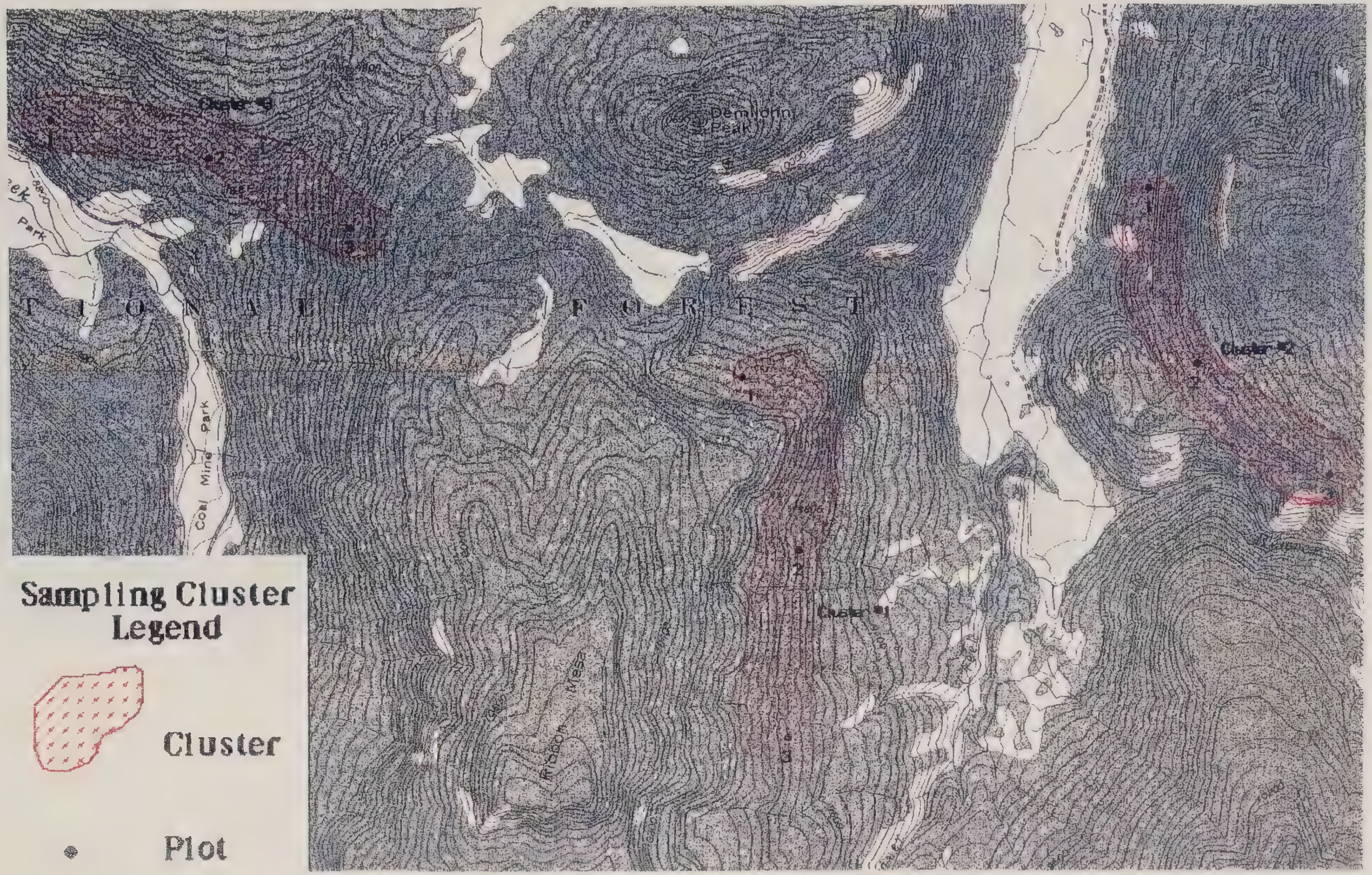
APPENDIX D

Alder Creek Area
Spruce Budworm Sampling Clusters



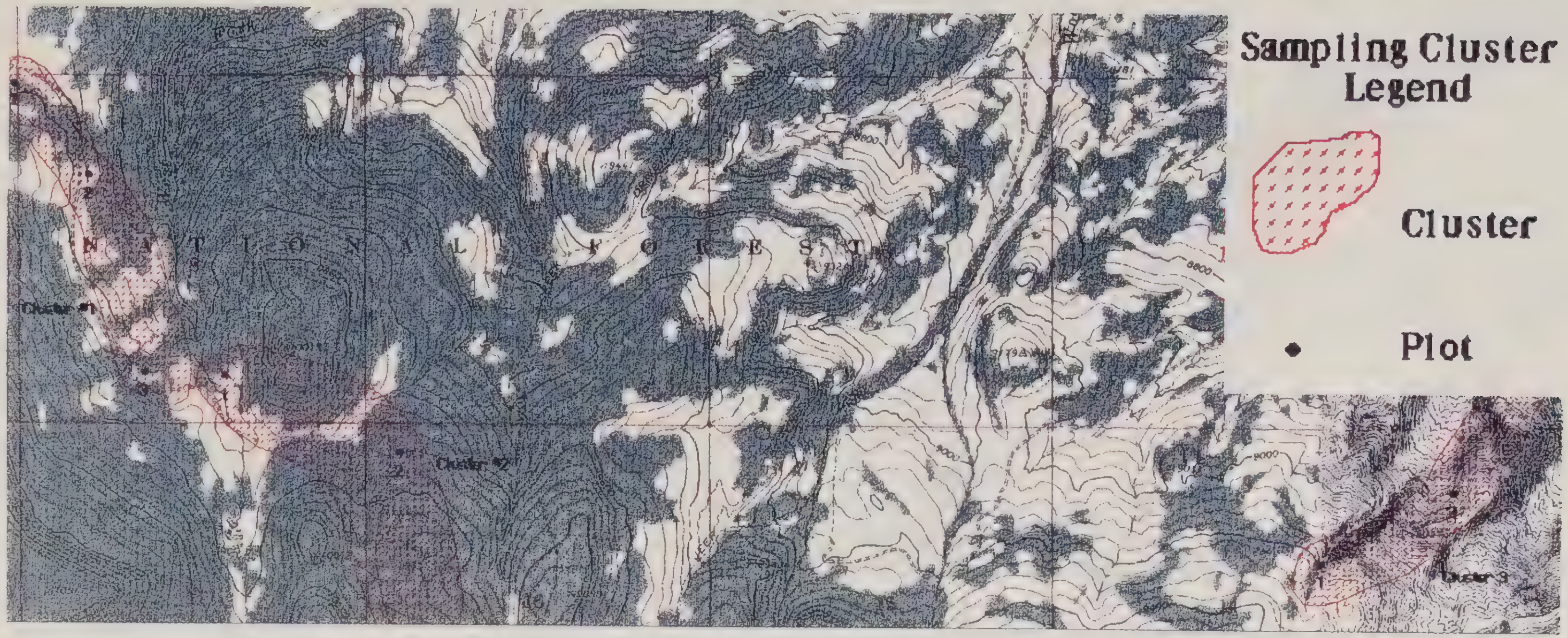
APPENDIX E

Beaver Creek Area
Spruce Budworm Sampling Clusters



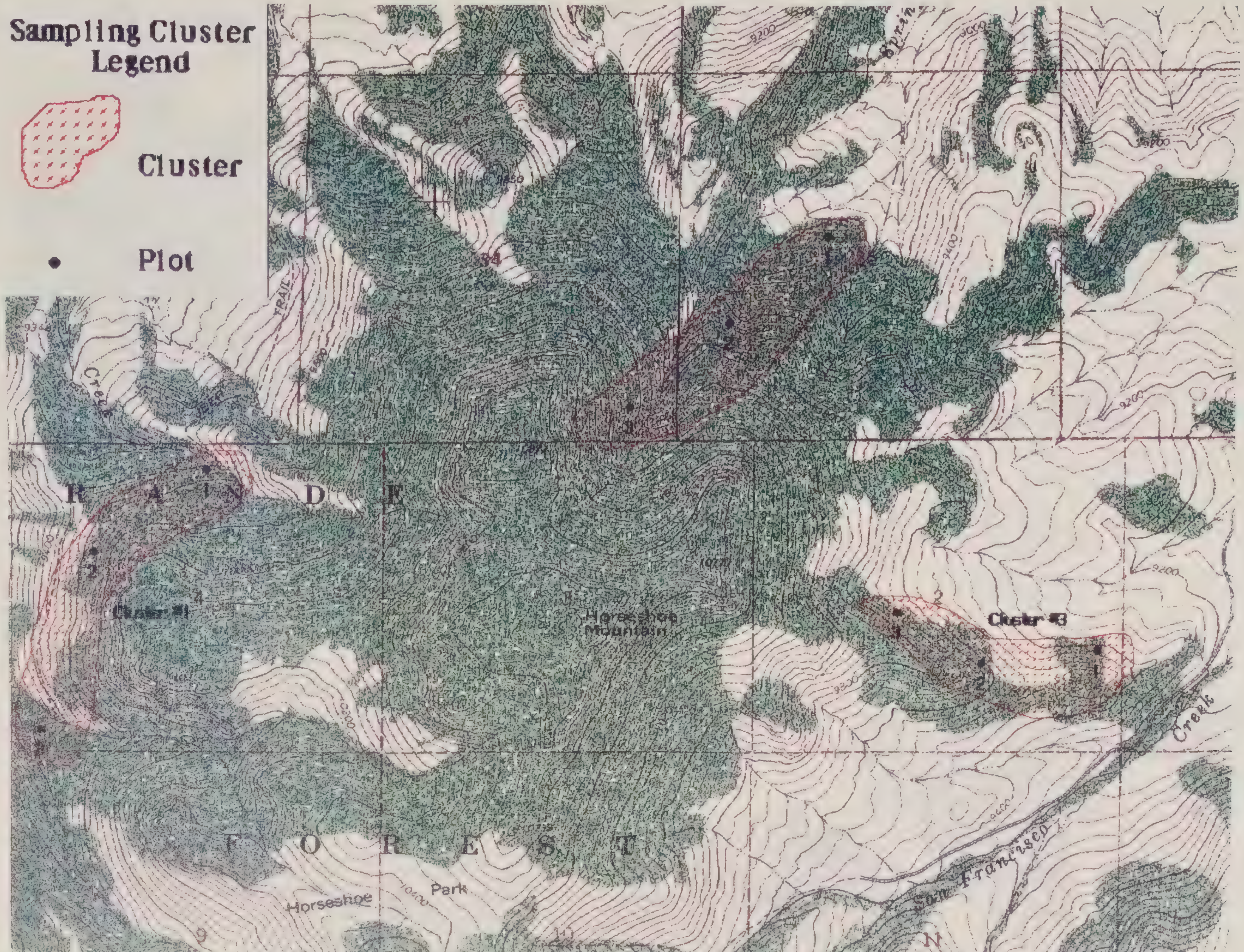
APPENDIX F

Del Norte Area
Spruce Budworm Sampling Clusters



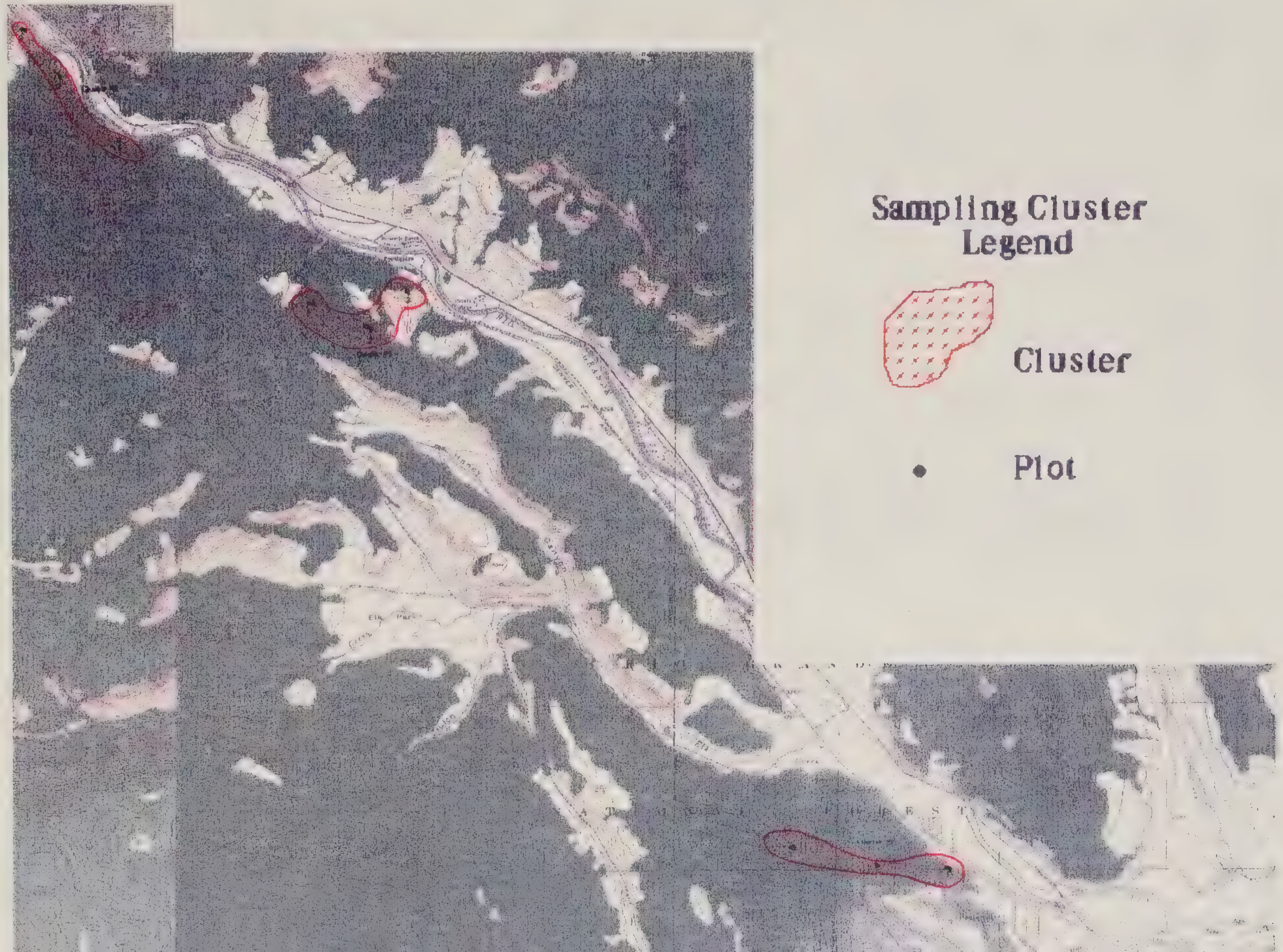
APPENDIX G

Horseshoe Mountain Area Spruce Budworm Sampling Clusters



APPENDIX H

Haney Canyon Area
Spruce Budworm Sampling Clusters



APPENDIX I

1992 WESTERN SPRUCE BUDWORM EGG MASS AND DEFOLIATION DATA

AREA: AGUA RAMON
CLUSTER: 1

PLOT	TREE/ BRANCH	L	W	AREA (SQ M)	NEW EGGS	EGGS/ SQ M	DEFOL TALLY	DEFOL CLASS
1	1	67	38		0	0	0/25	
1	2	52	35		0	0	3/25	
1	3	67	10		2	59.70	3/25	
1	4	46	38		0	0	17/18	
1	5	61	53		0	0	6/25	
1	6	67	31		0	0	11/25	
PLOT MEAN						9.95		.311
2	1	62	53		0	0	24/25	
2	2	66	40		0	0	24/25	
2	3	72	50		0	0	18/25	
2	4	69	79		0	0	11/25	
2	5	55	41		0	0	21/25	
2	6	59	50		0	0	11/25	
PLOT MEAN						0		.727
3	1	60	24		0	0	10/25	
3	2	55	33		0	0	12/25	
3	3	62	45		0	0	9/25	
3	4	49	56		0	0	3/25	
3	5	56	34		0	0	15/25	
3	6	55	41		0	0	18/25	
PLOT MEAN						0		.447
CLUSTER MEAN						3.32		.495

AREA: AGUA RAMON
CLUSTER: 2

PLOT	TREE/ BRANCH	L	W	AREA (SQ M)	NEW EGGS	EGGS/ SQ M	DEFOL TALLY	DEFOL CLASS
1	1	68	47		0	0	25/25	
1	2	53	33		0	0	23/14	
1	3	66	20		0	0	30/25	
1	4	71	27		0	0	13/25	
1	5	71	40		0	0	11/25	
1	6	54	45		0	0	18/25	
PLOT MEAN						0		.921
2	1	66	27		0	0	9/25	
2	2	61	34		0	0	4/25	
2	3	61	22		0	0	5/25	
2	4	58	34		0	0	15/14	
2	5	64	30		0	0	24/25	
2	6	50	46		0	0	28/25	
PLOT MEAN						0		.645
3	1	62	34		0	0	9/25	
3	2	66	24		0	0	10/25	
3	3	56	35		0	0	14/25	
3	4	67	40		0	0	2/25	
3	5	62	36		0	0	0/25	
PLOT MEAN						0		.287
CLUSTER MEAN						0		.618
AREA MEAN						1.67		.371

APPENDIX I

1992 WESTERN SPRUCE BUDWORM EGG MASS AND DEFOLIATION DATA

AREA: ALDER CREEK
CLUSTER: 1

PLOT	TREE/ BRANCH	L	W	AREA (SQ M)	NEW EGGS	EGGS/ SQ M	DEFOL TALLY	DEFOL CLASS
1	1	62	38	.118	0	0	122/25	
1	2	60	42	.126	0	0	118/25	
1	3	63	37	.117	8	68.38	99/25	
1	4	60	25	.075	4	53.33	95/21	
1	5	59	38	.112	4	35.71	121/25	
1	6	61	36	.110	2	18.18	81/17	
PLOT MEAN						29.27		
2	1	45	48		0	0	34/25	
2	2	60	37	.111	2	18.02	41/25	
2	3	65	75	.244	2	8.20	35/25	
2	4	71	33	.117	2	17.09	63/25	
2	5	62	67	.208	1	4.81	37/25	
2	6	65	41	.133			85/25	
PLOT MEAN						1.17		1.97
3	1	63	27		0	0	6/13	
3	2	64	38	.122	1	8.20	17/25	
3	3	65	38		0	0	5/25	
3	4	52	33		0	0	32/15	
3	5	59	44		1	7.69	24/25	
3	6	68	27		0	0	17/25	
PLOT MEAN						2.65		.85
CLUSTER MEAN						13.31		

AREA: ALDER CREEK
CLUSTER: 2

1	1	67	47	.157			9/25	
1	2	67	35	.117			19/15	
1	3	63	35	.110			2/21	
1	4	69	36	.124			18/18	
1	5	71	35	.124			28/21	
1	6	66	48	.158			7/25	
PLOT MEAN				.132	.67	5.05		.72
2	1	60	27	.081	3	37.04	37/14	
2	2	57	20		0	0	56/25	
2	3	55	22	.061	1	16.39	9/25	
2	4	42	23	.048	1	20.83	46/25	
2	5	56	28	.078	1	12.82	65/25	
2	6	92	29		0	0	36/17	
PLOT MEAN						14.51		1.97
3	1	48	33		0	0	37/25	
3	2	54	46	.124	2	16.13	55/25	
3	3	57	37		0	0	5/6	
3	4	66	45		0	0	62/25	
3	5	62	25		0	0	30/25	
3	6	58	32	.093	2	21.51	41/25	
PLOT MEAN						6.27		1.64
CLUSTER MEAN						8.61		1.44

APPENDIX I (Cont'd.)

1992 WESTERN SPRUCE BUDWORM EGG MASS AND DEFOLIATION DATA

AREA: ALDER CREEK
CLUSTER: 3

PLOT	TREE/ BRANCH	L	W	AREA (SQM)	NEW EGGS	EGGS/ SQ M	DEFOL TALLY	DEFOL CLASS
1	1	67	31		0	0	45/12	
1	2	70	30		0	0	77/16	
1	3	65	56	.182	2	10.99	64/25	
1	4	65	35	.114	4	35.09	72/25	
1	5	73	30		0	0	31/17	
1	6	70	25	.088	2	22.73	67/22	
PLOT MEAN						11.47		3.15
2	1	55	36	.099	3	30.30	27/25	
2	2	51	40		0	0	50/25	
2	3	48	36		0	0	36/25	
2	4	53	22		0	0	41/25	
2	5	64	26		0	0	73/25	
2	6	58	33	.096	1	10.42	80/25	
PLOT MEAN						6.79		2.05
3	1	68	52		0	0	23/23	
3	2	66	47		0	0	47/25	
3	3	66	53	.175	1	5.71	74/25	
3	4	67	43	.144	1	6.94	60/25	
3	5	74	32		0	0	36/13	
3	6	68	30		0	0	18/13	
PLOT MEAN						2.11		2.07
CLUSTER MEAN						6.79		2.42
AREA MEAN						9.57		2.11

AREA: BEAVER CREEK
CLUSTER: 1

1	1	62	47	.146	0	0	50/25	
1	2	58	48	.139	1	7.19	19/25	
1	3	55	45	.124	0	0	37/25	
1	4	55	41	.113	1	8.85	38/18	
1	5	54	52	.140	0	0	16/14	
1	6	48	52	.125	1	8.00	84/25	
PLOT MEAN				.131		4.01		1.81
2	1	60	49	.147	0	0	26/25	
2	2	64	35	.112	0	0	9/25	
2	3	65	72	.234	0	0	10/25	
2	4	71	48	.170	0	0	11/25	
2	5	60	48	.144	0	0	34/25	
2	6	64	51	.163	0	0		
PLOT MEAN						0		.71
3	1	56	43		0	0	31/25	
3	2	60	30		0	0	32/25	
3	3	53	51		0	0	15/25	
3	4	48	21		0	0	32/20	
3	5	63	32		0	0	43/25	
3	6	68	30	.102	1	9.80	21/25	
PLOT MEAN						0		1.21
CLUSTER MEAN						1.88		1.25

APPENDIX I (Cont'd.)

1992 WESTERN SPRUCE BUDWORM EGG MASS AND DEFOLIATION DATA

AREA: BEAVER CREEK
CLUSTER: 2

PLOT	TREE/ BRANCH	L	W	AREA (SQM)	NEW EGGS	EGGS/ SQ M	DEFOL TALLY	DEFOL CLASS
1	1	46	26	.060	1	16.72	67/25	
1	2	58	41	.119	3	8.41	53/25	
1	3	63	33	.104	2	9.62	40/25	
1	4	60	19	.057	2	35.09	78/25	
1	5	53	24		0		43/25	
1	6	55	31	.085	1	11.77	46/25	
PLOT MEAN						13.60		2.18
2	1	64	74				44/25	
2	2	59	35				44/25	
2	3	61	45				17/25	
2	4	67	28				3/25	
2	5	66	27				24/19	
2	6	64	25				9/12	
PLOT MEAN				.101		9.90		1.06
3	1	54	26		0	0	23/25	
3	2	52	17		0	0	11/14	
3	3	60	29	.087	2	11.49	66/23	
3	4	63	36	.113	3	7.69	50/25	
3	5	58	40		0		9/25	
3	6	49	18		0	0	1/7	
PLOT MEAN						3.20		1.18
CLUSTER MEAN						8.90		1.47

AREA: BEAVER CREEK
CLUSTER: 3

PLOT	TREE/ BRANCH	L	W	AREA (SQM)	NEW EGGS	EGGS/ SQ M	DEFOL TALLY	DEFOL CLASS
1	1	52	66		0	0	56/25	
1	2	54	46		0	0	61/25	
1	3	68	50		0	0	30/25	
1	4	65	49		0	0	23/25	
1	5	64	44		0	0	5/25	
1	6	53	37		0	0	11/25	
PLOT MEAN						0		1.24
2	1	58	26		0	0	52/25	
2	2	56	34		0	0	52/25	
2	3	50	32		0	0	29/17	
2	4	65	50	.163	3	18.41	38/25	
2	5	57	37	.105	1	9.52	60/25	
2	6	53	36	.095	2	21.05	33/25	
PLOT MEAN						8.16		1.85
3	1	58	27		0	0	75/25	
3	2	48	34		0	0	59/25	
3	3	45	38	.086	1	11.63	11/25	
3	4	47	44		0	0	33/21	
3	5	56	24		0	0	36/20	
3	6	60	26		0	0	11/25	
PLOT MEAN						1.94		1.60
CLUSTER MEAN						3.37		1.56
AREA MEAN						4.72		1.43

APPENDIX I (Cont'd.)

1992 WESTERN SPRUCE BUDWORM EGG MASS AND DEFOLIATION DATA

AREA: DEL NORTE
CLUSTER: 1

PLOT	TREE/ BRANCH	L	W	AREA (SQ M)	NEW EGGS	EGGS/ SQ M	DEFOL TALLY	DEFOL CLASS
1	1	68	34	.116	0	0.00	77/25	
1	2	74	54	.200	3	15.00	68/25	
1	3	69	53	.183	4	21.86	38/25	
1	4	67	50	.168	2	11.91	88/25	
1	5	69	50	.173	1	5.78	67/25	
1	6	68	71	.241	10	41.49	97/25	
PLOT MEAN				.180	3.33	16.01		2.90
2	1	65	32	.104	1	9.62	74/25	
2	2	49	20	.049	0	0.0	89/25	
2	3	47	24	.056	1	17.86	65/25	
2	4	72	38	.137	2	14.60	112/25	
2	5	68	39	.133	1	7.52	81/25	
2	6	48	18	.043	3	69.77	100/25	
PLOT MEAN				.087	1.33	19.90		3.31
3	1	65	43	.140	2	14.29	24/25	
3	2	69	34	.117	0	0	60/25	
3	3	61	37	.113	1	8.85	71/25	
3	4	68	30	.102	3	29.41	69/25	
3	5	73	24	.088	0	0	65/25	
3	6	51	30	.077	0	0	59/25	
PLOT MEAN				.106	1.00	8.76		2.32
CLUSTER MEAN				.124	1.89	14.89		2.84

AREA: DEL NORTE
CLUSTER: 2

PLOT	TREE/ BRANCH	L	W	AREA (SQ M)	NEW EGGS	EGGS/ SQ M	DEFOL TALLY	DEFOL CLASS
1	1	60	43	.129	1	7.75	61/25	
1	2	65	49	.159	4	25.16	45/25	
1	3	66	45	.149	0	0	82/25	
1	4	54	23	.062	0	0	87/25	
1	5	56	22	.062	0	0	53/25	
1	6	64	52	.166	1	6.02	38/25	
PLOT MEAN				.121	1.00	6.49		2.28
2	1	63	42	.132	1	7.58	97/25	
2	2	57	29	.083	3	36.15	58/25	
2	3	63	30	.095	6	63.16	62/25	
2	4	67	40	.134	1	7.46	62/25	
2	5	66	59	.195	1	5.13	53/25	
2	6	69	34	.117	1	8.55	62/25	
PLOT MEAN				.126	2.17	21.34		2.63
3	1	64	37	.118			16/15	
3	2	70	45	.158			27/25	
3	3	65	35	.114			22/11	
3	4	69	47	.162			27/25	
3	5	67	48	.161			44/25	
3	6	66	53	.175			41/25	
PLOT MEAN				.148	1.67	11.28		1.44
CLUSTER MEAN				.132	1.61	13.04		2.12

APPENDIX I (Cont'd.)

1992 WESTERN SPRUCE BUDWORM EGG MASS AND DEFOLIATION DATA

AREA: DEL NORTE
CLUSTER: 3

PLOT	TREE/ BRANCH	L	W	AREA (SQM)	NEW EGGS	EGGS/ SQ M	DEFOL TALLY	DEFOL CLASS
1	1	64	30	.096	0		47/25	
1	2	70	38	.133	0		21/25	
1	3	66	41	.135	0		25/25	
1	4	70	51	.179	0		8/25	
1	5	60	62	.186	0		22/25	
1	6	67	47	.157	0		29/25	
PLOT MEAN				.148	0			1.01
2	1	66	42	.139	0		15/21	
2	2	67	45	.151	0		50/25	
2	3	63	50	.158	0		11/20	
2	4	67	42	.141	0		17/18	
2	5	64	48	.154	0		39/24	
2	6	64	53	.170	0		15/25	
PLOT MEAN				.152	0	0		1.07
3	1	70	58	.203	0		6/25	
3	2	63	46	.145	0		47/25	
3	3	69	52	.179	2	11.17	21/25	
3	4	53	44	.117	1	8.55	19/25	
3	5	60	40	.120	0		34/25	
3	6	50	32	.105	0		11/25	
PLOT MEAN				.145	.50	3.29		.92
CLUSTER MEAN				.148	.17	1.10		1.00
AREA MEAN				.135	1.22	9.67		1.99

AREA: HANEY CANYON
CLUSTER: 1

PLOT	TREE/ BRANCH	L	W	AREA (SQM)	NEW EGGS	EGGS/ SQ M	DEFOL TALLY	DEFOL CLASS
1	1	46	22	.051	0		56/20	
1	2	66	48	.158	0		105/25	
1	3	59	43	.127	3	23.62	35/25	
1	4	79	38	.150	4	26.67	27/25	
1	5	59	35	.103	4	38.84	21/25	
1	6	60	43	.129	3	23.26	33/25	
PLOT MEAN				.120	2.33	18.73		1.94
2	1	61	29	.088	2	22.73	30/25	
2	2	56	54	.151	6	39.74	62/25	
2	3	67	29	.097	2	20.62	48/25	
2	4	71	32	.114	3	26.32	32/25	
2	5	66	57	.188	2	10.64	62/25	
2	6	57	35	.100	2	20.00	64/25	
PLOT MEAN				.123	2.83	23.34		1.99
3	1	66	35	.116	3	25.86	10/17	
3	2	76	23	.087	0	0	32/20	
3	3	68	34	.116	0	0	7/22	
3	4	70	46	.161	0	0	22/25	
3	5	65	45	.146	2	13.70	16/15	
3	6	72	53	.191	2	10.47	42/25	
PLOT MEAN				.136	1.17	8.34		1.02
CLUSTER MEAN				.126	2.11	16.80		1.65

APPENDIX I (Cont'd.)

1992 WESTERN SPRUCE BUDWORM EGG MASS AND DEFOLIATION DATA

AREA: HANEY CANYON
CLUSTER: 2

PLOT	TREE/ BRANCH	L	W	AREA (SQM)	NEW EGGS	EGGS/ SQ M	DEFOL TALLY	DEFOL CLASS
1	1	61	38	.116			61/25	
1	2	65	22	.072			40/25	
1	3	58	20	.058			47/25	
1	4	69	43	.148			59/25	
1	5	60	35	.105			71/25	
1	6	69	25	.086			24/21	
PLOT MEAN				.098	.33	3.40		2.04
2	1	67	27	.090	1	11.11	99/25	
2	2	72	20	.072	0	0	98/25	
2	3	63	38	.120	1	8.33	107/25	
2	4	60	29	.087	2	22.99	85/25	
2	5	70	29	.102	2	19.61	73/25	
2	6	60	40	.120	3	25.00	86/25	
PLOT MEAN				.099	1.50	14.51		3.65
3	1	67	29	.097	0	0	88/25	
3	2	66	33	.109	4	36.70	91/25	
3	3	70	44	.154	0	0	123/25	
3	4	74	49	.181	1	5.53	94/25	
3	5	60	40	.120	2	16.67	97/25	
3	6	64	43	.138	4	28.99	72/25	
PLOT MEAN				.133	1.83	14.65		3.77
CLUSTER MEAN				.347	1.22	10.85		3.15

AREA: HANEY CANYON
CLUSTER: 3

PLOT	TREE/ BRANCH	L	W	AREA (SQM)	NEW EGGS	EGGS/ SQ M	DEFOL TALLY	DEFOL CLASS
1	1	70	43	.151	2	13.25	77/25	
1	2	58	40	.116	4	34.48	70/25	
1	3	60	38	.114	4	35.09	64/25	
1	4	61	31	.095	1	10.53	59/25	
1	5	76	39	.148	2	13.51	48/25	
1	6	68	40	.136	3	22.06	92/25	
PLOT MEAN				.127	2.67	21.49		2.73
2	1	65	45	.146	0	0	123/25	
2	2	59	24	.071	2	28.17	125/25	
2	3	63	38	.120	6	50.00	124/25	
2	4	65	21	.068	2	29.41	123/25	
2	5	64	36	.115	3	26.09	119/25	
2	6	67	41	.137	3	21.90	124/25	
PLOT MEAN				.110	2.67	25.93		4.92
3	1	64	33	.106	0	0	58/25	
3	2	74	44	.163	0	0	68/25	
3	3	67	34	.114	0	0	31/25	
3	4	64	43	.138	1	7.25	66/25	
3	5	71	42	.149	1	6.71	83/25	
3	6	67	23	.077	1	12.99	68/21	
PLOT MEAN				.125	.50	4.49		2.58
CLUSTER MEAN				.120	1.94	17.30		3.41
AREA MEAN				.121	1.76	14.99		2.74

APPENDIX I (Cont'd.)

1992 WESTERN SPRUCE BUDWORM EGG MASS AND DEFOLIATION DATA

AREA: HORSESHOE MTN.
CLUSTER: 1

PLOT	TREE/ BRANCH	L	W	AREA (SQM)	NEW EGGS	EGGS/ SQ M	DEFOL TALLY	DEFOL CLASS
1	1	67	42	.141	0	0	22/25	
1	2	65	33	.107	0	0	27/25	
1	3	72	40	.144	0	0	13/25	
1	4	67	33	.111	0	0	26/25	
1	5	61	37	.113	1	8.85	14/25	
1	6	69	24	.083	0	0	15/25	
PLOT MEAN				.117	.17	1.48		.78
2	1	65	50	.163	0	0	20/25	
2	2	74	34	.126	0	0	12/25	
2	3	46	37	.085	0	0	11/25	
2	4	65	50	.163	0	0	17/25	
2	5	71	41	.146	0	0	17/25	
2	6	59	52	.153	0	0	13/25	
PLOT MEAN				.139	0	0		.60
3	1	62	23	.071	0	0	11/25	
3	2	69	35	.121	0	0	2/25	
3	3	51	29	.074	0	0	10/25	
3	4	64	31	.099	0	0	1/25	
3	5	56	31	.087	0	0	32/25	
3	6	65	27	.088	0	0	8/25	
PLOT MEAN				.090	0	0		.43
CLUSTER MEAN				.115	.06	.49		.60

AREA: HORSESHOE MOUNTAIN
CLUSTER: 2

PLOT	TREE/ BRANCH	L	W	AREA (SQM)	NEW EGGS	EGGS/ SQ M	DEFOL TALLY	DEFOL CLASS
1	1	69	42	.145	1	6.90	19/25	
1	2	63	48	.151	0	0	44/25	
1	3	61	37	.113	0	0	41/25	
1	4	62	32	.099	0	0	17/25	
1	5	62	44	.136	0	0	17/25	
1	6	64	27	.086	0	0	50/25	
PLOT MEAN				.122	.17	1.15		1.25
2	1	64	46	.147	3	20.41	73/25	
2	2	66	42	.139	2	14.39	41/25	
2	3	66	22	.073	1	13.70	88/25	
2	4	65	44	.143	0	0	80/25	
2	5	64	40	.128	1	7.81	21/25	
2	6	66	55	.182	0	0	93/25	
PLOT MEAN				.135	1.17	9.39		2.64
3	1	62	50	.155	0	0	33/25	
3	2	65	33	.107	1	9.35	59/25	
3	3	52	27	.070	0	0	83/25	
3	4	58	32	.093	0	0	47/25	
3	5	64	45	.144	2	13.89	54/25	
3	6	68	37	.126	0	0	40/25	
PLOT MEAN				.116	.50	3.87		2.11
CLUSTER MEAN				.124	.61	4.80		2.00

1992 WESTERN SPRUCE BUDWORM EGG MASS AND DEFOLIATION DATA

AREA: HORSESHOE MTN.
CLUSTER: 3

PLOT	TREE/ BRANCH	L	W	AREA (SQM)	NEW EGGS	EGGS/ SQ M	DEFOL TALLY	DEFOL CLASS
1	1	67	45	.151	0	0	4/25	
1	2	59	28	.083	0	0	13/25	
1	3	66	31	.102	0	0	9/25	
1	4	60	24	.072	0	0	19/25	
1	5	65	27	.088	0	0	10/25	
1	6	60	23	.069	0	0	25/25	
PLOT MEAN				.094	0	0		.53
2	1	61	42	.128	0	0	9/25	
2	2	47	27	.063	0	0	31/21	
2	3	53	34	.090	0	0	45/25	
2	4	62	41	.127	0	0	12/25	
2	5	54	43	.116	0	0	16/25	
2	6	62	32	.099	0	0	30/25	
PLOT MEAN				.104	0	0		.99
3	1	65	32	.104	0	0	27/19	
3	2	64	38	.122	2	16.39	48/25	
3	3	64	44	.141	1	7.09	40/25	
3	4	65	42	.137	0	0	49/25	
3	5	64	33	.106	2	18.87	49/15	
3	6	66.	50	.165	1	6.06	51/23	
PLOT MEAN				.129	1.00	8.07		2.06
CLUSTER MEAN						2.69		1.20
AREA MEAN						2.66		1.27